A REVIEW ON HEALTH EFFECTS ASSOCIATED WITH PROLONGED STANDING IN THE INDUSTRIAL WORKPLACES

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ABSTRACT
In industrial workplaces, many workers perform processes jobs in standing position for a long period of time. Working in standing position can be linked to versatility because the mobility of legs position and having large degree of freedom. This working position promotes workers to be more efficient and productive. Such advantages contribute high value for company profits; however, standing in a long period of time can lead to discomfort, muscle fatigue, and occupational injuries to workers. The purpose of this paper is to disseminate information on health effects, assessment methods, and control measures associated with prolonged standing jobs in industrial workplaces. Published articles related to standing in workplace have been reviewed. Based on published researches, work-related musculoskeletal disorders, chronic venous insufficiency, preterm birth and spontaneous abortion, and carotid atherosclerosis have been identified as common health problems associated with prolonged standing. Engineering and administrative controls have been proposed to the workplace to minimize the health problems.

Keywords: *Prolonged standing, Industrial workplaces, Health effects, Assessment methods, Control measures*

1. INTRODUCTION

Many processes jobs in industrial workplaces are effective if performed in standing position. Among significant rationales to perform jobs in standing are: 1) the worker requires large degree of freedom while performing the processes jobs, especially operating large machine and huge workpieces, reaching of materials and tools, and pushing and pulling of excessive loads. For instance, a worker who works at a conventional milling machine requires large degree of freedom of working orientation when he pushes and pulls the milling table to mill the workpiece. This kind of job nature does not permit the worker to perform the milling process in sitting position; and 2) the design of machine or the workstation does not allow worker to perform the processes jobs in sitting position. For example, standing position is commonly practiced by a lathe operator because the design of lathe machine does not provide adequate space for the operator to position his legs in sitting position. Other reasons may be the worker prefers to stand instead of sitting even though the processes jobs can be performed in sitting position, and/ or the workstation is not equipped with sitting facility.

Working in standing can be considered as versatile position because the mobility of legs and having large degree of freedom. The position enables a worker to perform the processes jobs in an easy and efficient way. As an impact, this working position makes the worker more productive and consequently contributes to high productivity to the industry. However, when workers spent a long period of time in standing position throughout their working hours, they may feel discomfort and experienced muscle fatigue at the end of workday. In the long terms, they will potentially experienced occupational injuries. A worker is considered to be exposed to prolonged standing if he/ she spent over fifty percent of the total working hours during a full work shift in standing position [1]. Working in standing position for a long period of time has been recognized as a vital contributor to decrease workers' performance in industry. It includes occupational injuries, productivity decrement, increased of treatment and medical costs, and demoralize workers. When workers perform jobs in prolonged standing, static contraction occurred particularly in their back and legs, thus resulted in diminished function of calf muscle [2]. This condition leads to discomfort and muscle fatigue to the workers. Besides, the employers will lost revenue in the forms of productivity, workers' compensation and health treatment costs [3]. For example, pain in the lower back associated with prolonged standing can effect the ability of a worker to perform bending posture or body twisting in his or her routine job. This may in turn affect the productivity of the worker. In addition, workers who suffered from occupational injuries must be referred to clinical experts for health treatment, which definitely involve substantial amount of consultancy and medical costs.

In recognition the importance of managing standing jobs safely, this paper was prepared to disseminate information on health effects, assessment methods, and control measures associated with performing jobs in prolonged standing. The information may be useful as a guideline to safety and health committees in industry to improve their workplaces so as to enhance occupational health.

2. HEALTH EFFECTS

Occupational health statistics estimated that hundred of thousands of workers in the United Kingdom have suffered from injuries due to prolonged standing, and resulted over 2 million days sick leave a year [4]. As a common symptom, worker who performs processes jobs in a long duration of standing may experience discomfort in the legs, neck and shoulder. If the standing position is continuously practiced and remedy actions for workplace improvement are taken passively, the worker may feel discomfort and fatigue particularly in the lower limb muscles (legs and thighs), lower back, and feet. As long term consequences, prolonged standing contributes severe health problems such as chronic venous disorders, circulatory problems, possibility of increase stroke risk, difficulty in pregnancy, and degenerative damage to the joints of the spine, hip, knees and feet. Based on previous studies, work-related musculoskeletal disorders, chronic venous insufficiency, preterm birth and spontaneous abortion, and carotid atherosclerosis have been identified as common health problems associated with prolonged standing.

2.1. Work-related Musculoskeletal Disorders (WMSD)

Work-related musculoskeletal disorders (WMSD) refers to conditions where the workers have experienced discomfort in one or multiple body parts (neck, shoulder, back, elbow, hand, hip and knee), pain in the joints, tingling, and swelling. It is well known that prolonged standing has been linked to the onset of work-related musculoskeletal disorders associated with lower back pain among industrial workers [5]. A hypothesized reason for the increased discomfort and whole body fatigue associated with prolonged standing conditions is reduced blood circulation in the lower legs and localized muscle fatigue [6]. Reduced blood circulation results in blood pooling, commonly represented as foot and lower leg swelling [3]. Duration of standing also identified as a significant contributor to WMSD. When workers perform jobs in standing position for more than 4 hours each day, they will potentially exposed to WMSD associated with lower back pain [7]. Recent study reported that around 50 percent of healthy respondents reported discomfort in the lower back, even though exposed after 2 hours of continuous standing [8]. In spite of discomfort and pain in the lower back, prolonged standing also caused pain in the feet [9], [10]. A study revealed that pain in the feet is commonly reported during standing position compared to sedentary or walking tasks [11].

Prolonged standing transfers the load of upper body to the lower parts thus resulted to lower back pain. The American Podiatric Association reported that 83% of industrial workers in the United States experienced foot or lower leg pain and discomfort associated with prolonged standing [3]. A cross-sectional study found that there were significant associations between WMSD (pain in the back, lower leg, and shoulder pain) and prolonged standing [12], [13]. Meanwhile, a study revealed that combination of prolonged standing and lifting weights have led to high pain prevalence in the lower back and lower limbs for 906 women at 24 semiconductor factories in Malaysia [14].

2.2. Chronic Venous Insufficiency (CVI)

The chronic venous insufficiency (CVI) describes a condition that affects the venous system of the lower extremities and causing venous hypertension including pain, swelling, oedema, skin changes, and ulcerations in the legs [15]. The CVI at lower extremities promotes various clinical symptoms due to valvular incompetence, venous dilation and consecutive venous hyperpressure [16]. Varicose vein is one of the common symptoms of CVI. A worker is suspected to have varicose vein when his/ her leg's veins become twisted and swollen. Usually, varicose vein occurs when the workers sustained high pressure while performing jobs in standing position, and normally the pain in the legs will be felt when they are standing or walking. The duration of standing was recognized as a vital contributor to CVI. A study pointed that workers who stand more than 50 percent of working hours exhibited a higher frequency of CVI than workers who spent less time in standing [1].

2.3. Preterm Birth and Spontaneous Abortion

Few studies agreed that prolonged standing is a risk factor for preterm birth and spontaneous abortion among working pregnancy women [17], [18], [19]. It is reported that pregnant women who are stood more than 8 hours in a working day have high chance for spontaneous abortion (provided by a previous history of spontaneous abortion) [17].

2.4. Carotid Atherosclerosis

Atherosclerosis is the build up of a waxy plaque on the inside of blood vessels. Atherosclerosis can cause heart attack if it completely blocks the flow of blood to the heart. Few studies have linked working conditions with cardiovascular problems [20], [21]. A study found that there was a significant progression of atherosclerosis among men who are exposed to prolonged standing in the workplace [22].

3. ASSESSMENT METHODS

The severity of health effects associated with prolonged standing depends on several factors such as number of risk factors, number of complaints from the workers, number of injury cases reported in the medical record, quality decrement of the products being manufactured and high percentage of symptoms of pains and discomfort in the body parts [23]. Nowadays, there are methods and tools that could be utilized to identify, assess, and analyze discomfort and muscle fatigue associated with prolonged standing. The methods can be categorized into subjective and direct technical measurement methods, and they can be used either at a real workplace in industry or a laboratory setting.

3.1. Subjective Method

Subjective method is used to obtain psychological feedbacks from the respondents (workers). Normally the subjective method is applied through personal interview and questionnaire survey. In subjective method, the Borg Scale (or called Rating Perceived Exertion RPE), and the Visual Analogue Scale (VAS) are commonly used. The Borg Scale is used to measure perceived exertion experienced by the respondents [24]. It was established by Gunnar Borg, whereby a scale of 6 to 20 was introduced. Later, the original scale is revised to 0 to 10 by many practitioners. Meanwhile, VAS is commonly used to measure perceived exertion among respondents through questionnaire survey. The VAS is a psychometric response scale which can help respondents to specify level of agreements (e.g. comfort, moderate comfort, discomfort) by indicating a position along a continuous line between two end-points. Interestingly, VAS is comparable to Borg Scale as both tools have shown very similar results in terms of sensitivity and reproducibility [25].

In the earliest study on prolonged standing, subjective method using Borg Scale was applied to classify posture comforts on the basis of maximum holding time (MHT). The study found that a comfort posture can be obtained when workers dealt with moderate working height (50%, 75%, 100%, 125% from shoulder height) and small working distance (25%, 50% from arm reach). The moderate comfort posture could be obtained if the work is performed at moderate working height (50%, 75%, 100%, 125% from shoulder height) and large working distance (75%, 100% from arm reach). On the other hand, discomfort posture is recognized when the working height is too low or too high than 25% and 150% of shoulder height respectively [26].

A year later, a study was conducted to examine the differences between subjective, physiological and biomechanical responses among individuals during prolonged standing. Rate of intensity of unpleasantness (scale of 0 to 10) was applied. The study revealed that a reduced subjective effect of the soft surface on the intensity of unpleasantness accompanied by low postural activity and no swelling of the shank [6]. In another study, a modified questionnaire was used to determine subjective ratings from the respondents due to different work-rest schedules (60 min shift-15 min break; 45 min shift-15 min break; 30 min shift-15 min break; 30 min shift-30 min break). The study highlighted that there is a significant effect of the work-rest schedule on subjective ratings of discomfort [27]. Niklas (2000) conducted a survey on the carotid intima media thickness associated with prolonged standing among patients with heart disease using a set of questionnaire. The study found that men with heart disease appear especially vulnerable to the adverse effects associated with standing at work [22].

King (2002) applied questionnaires to investigate the effects of four different standing conditions: (i) on hard floor, (ii) on a floor mat, (iii) wearing shoe-insoles, (iv) wearing shoe-insoles while standing on a floor mat. The study found that the highest ratings for firmness, general fatigue and leg fatigue were reported when standing on a hard floor, meanwhile discomfort ratings were lowest for standing on mat and wearing shoe-insoles [28].

Beside Borg Scale and VAS, survey form was also established to investigate discomfort and subjective fatigue due to standing at workplaces. Surveys using Body Part Symptom form revealed that all respondents who performed jobs in standing position experienced discomfort and pain, and the frequency and level of discomfort occurrence are greater at lower extremities [29], [30]. A sectional survey using self-reporting survey form observed that eighteen percent of respondents (operatieassisten) stood more than four hours in working hours and exceeded the ergonomics guidelines on standing at work [31].

To date, Prolonged Standing Questionnaire was developed [32]. It is specifically established to obtain information regarding prolonged standing jobs at industrial workplaces. The Prolonged Standing Questionnaire records personal details and job activities of workers, discomfort and pain experienced by the workers while performing jobs in prolonged standing, history of pain and treatment taken, and suggestion for improvement.

3.2. Direct Technical Measurement Method

Dissimilar to subjective method, the direct technical measurement method measures and analyzes physiological and biomechanical responses of subjects. This method required scientific technical tools which can produce specific quantities such as frequency, distance, and temperature. The application of direct technical measurement method is always linked to direct contact between subjects and the measurement instruments. The advantages of utilizing direct technical measurement method are reliable data that could be acquired from the subjects and it is able to represent the actual condition of subjects during the experiments. In contrast, depends on instrument and measurement procedures, sometimes the direct technical measurement method may cause discomfort to the subjects during and/ or at the end of experiment sessions. Several tools that are commonly used for the assessment of prolonged standing are optical leg volume meter, perometer, volumeter, and surface electromyography (sEMG).

The optical leg volume meter consists of a frame containing infrared emitters on a horizontal and a vertical side and phototransistors on the opposite sides [33]. It has been recognized as an effective and reliable tool to evaluate the leg volume measurement in detection of chronic venous insufficiency [2]. In a study on physical work load, an optical leg volume meter was used to measure the lower legs volume at different work-rest schedules. The study observed that an average increase of 1.4% (SD 2.4) in total lower leg volume at the end of the work day, and the effect of the time during the day being highly significant ($p<0.001$) [27].

The perometer is an electromechanical device that used to measure limb cross section at multiple intervals for calculating limb volume. It has been applied to measure knee volume in subjects with impaired knee mobility [34].

The volumeter is a mechanical device that is utilized to measure volume of limb based on the amount of water displacement. Karl-Heinz et al., 2000 utilized a volumeter to measure limb circumferences at mid-calf and ankle level of both legs among 30 healthy subjects [35]. Zander (2004) used volumeter principle (Gulick Tape II) to measure lower leg circumferences to examine different flooring conditions at workplaces [3].

In occupational ergonomics, sEMG has been considered a reliable tool to assess localized muscle fatigue [36], [37]. It refers to non-invasive (on the skin surface) recordings of electrical signals which are generated by muscle contraction. Muscle fatigue due to prolonged standing exposures can be quantified by observing the changes in amplitude and frequency of electromyogram signals over time [38]. When the signal amplitude increases and power spectrum shifts to lower frequency, it indicates that the assessed muscles are in fatigue condition [37], [39], [40], [41].

Pascal et al., 1998 applied sEMG to examine physiological responses among healthy male subjects during standing on hard and soft surfaces. The study found that the muscle activity of tibialis anterior tended to increase when standing on the soft surface compared to the hard surface [6]. In another study, sEMG was applied to analyze physiological responses in relation to mat and shoe softness during prolonged work in upright position. The study found that the mean power frequency (MPF) change of sEMG was not influenced by shoe or floor softness [11]. Furthermore, Ahmad et al., 2006 utilized sEMG to study the influence of age on muscle fatigue of prolonged standing work. The study observed that the sEMG amplitude of older subjects was 46.5-67.7% higher than younger subjects [29]. The sEMG was also applied to assess the effect of wearing compression hosiery on four muscles group of nurses. The findings indicated that wearing compression hosiery produced high electromyography activity in the tibialis anterior and medial gastrocnemius [42]. A recent study utilized sEMG to determine possible mechanisms for the development of low back disorder during standing by monitoring biological variables. The study confirmed that very few measured variables revealed differences between individuals who developed low back disorder and those healthy [8].

4. CONTROL MEASURES

With respect to negative impacts of prolonged standing, studies and control measures should be treated as a priority so that related injuries can be eliminated or minimized. In ergonomics discipline, engineering controls and administrative controls were found to be effective methods to reduce the risk of occupational injuries in the industrial workplaces [43].

4.1. Engineering Controls

Engineering controls refer to the use of engineering techniques to minimize the risk of occupational injuries such as application of anti-fatigue mats and ergonomic footwear design to release muscle fatigue in the feet due to floor condition at the workplace. In engineering controls, various interventions have been reported to enhance occupational health due to prolonged standing exposures. Proper design of clothing for prolonged standing job has shown positive impacts. For instance, mild compression stockings reduced diurnal oedema and unpleasant feelings of the legs in healthy individuals [33]. Another study found that gradual compression hose may minimize oedema and muscle fatigue, thus increase comfort in the legs [44]. Krijnen et al., 1997 compared the efficacy between compression stockings and rubber mats. The result showed compression stockings appeared to be superior to rubber mats with regard to applicability, diminishing subjective complaints and decrease of diurnal leg swelling [2]. To date, wearing compression hosiery was recommended to alleviate lower body and foot discomfort for clinical nurses. In spite of compression stockings, outside arch support made of Ethylene Vinyl Acetate (EVA) materials that placed in the metatarsal zone able to minimize foot pressure distribution, impact force, and increase shin and ankle comfort [42]. To reduce stress in the heel, a heel counter (semi-rigid cup) was designed to fit around the heel.

This counter has clearly showed a potential solution [45]. Whistance et al., 1995 applied footrest to reduce lumbar lordosis. The footrest increased trunk flexion and it is not associated with significantly less discomfort [46]. Many researches revealed that floor mats and shoe in-soles are effective solutions to improve body comfort and occupational health during prolonged standing tasks. For example, King (2002) found that the floor mat, shoe in-soles and combined conditions were more comfortable than standing on hard floor [28]. However, floor mat and shoe in-soles may have little effect on controlling leg oedema for industrial workers exposed to standing for more than 8 hours shifts [3]. As far as lower extremities are concerned, localized muscular fatigue in the leg may not be relieved with anti-fatigue mats, but benefited the back [47]. Soft work surface has also shown a great potential to alleviate occupational injuries associated with prolonged standing exposures. Previous study has shown that the low mean power frequency (MPF) of EMG and decrement of calf surface temperature were observed when the subjects were exposed to standing on soft work surface. In addition, the experiment showed greater swelling developed when standing on the hard surface as compared to soft surface [6]. Furthermore, manual material handling activities are more comfortable when standing on a soft surface as compared to hard surface [47], [48], [49]. On the other hand, the soft surface reduced localized muscle fatigue only in the erector spinae muscle (lower back region) and not in the gastrocnemius and tibialis anterior muscles (legs region) [47].

Sitting can be much less strenuous working position than standing because it requires fewer muscles to be contracted to stabilize the body. Furthermore the loading on upper limbs will be uniformly distributed through the seat pan [50], thus reduce the loading on lower limbs. However, sitting in long periods of time is also not good for health. Alternate the standing and sitting positions using a sit-stand stool enables workers to perform the jobs in sitting and/ or standing. In addition, the sit-stand stool is equipped with foot rest that can provide comfort on workers' legs. Also, it can be rotated at 360 degrees so that the workers can reach the materials without twisting their body and enlarge degree of freedom to do the jobs.

4.2. Administrative Controls

In cases where engineering controls are impossible to be implemented due to various constraints, work-rest scheduling is the most commonly adopted through administrative controls to minimize the risk of prolonged standing. Work-rest schedule has been recognized as the most suitable method to alleviate the occupational injuries associated with prolonged standing. Jaap and Huub (1998) proved that providing longer breaks would be more effective to minimize risk of leg swelling associated with prolonged standing [27]. A previous study has recommended a shift from standing to seated working position during working hours in order to minimize muscle fatigue in the lower extremities [11]. Konz (2006) proposed to have some sitting, some standing and some walking for a job and process in the manufacturing environment. In addition, if a job requires 100% standing, a job rotation strategy within the shift was recommended [51]. Meanwhile O'Neill (2005) suggested other solutions such as reduce time spent for standing or walking, obtain suitable and adjustable chair, apply more rest breaks, and alternate standing and walking with sitting [4].

5. DISCUSSION

In industrial workplaces, workers prefer standing position because many processes jobs are practical to perform in this position, easy mobility for frequent movements, and having large degree of freedom. However, standing in a long period of time has lead to discomfort and fatigue among industrial workers. Many researches related to standing jobs have concentrated on duration of standing, working posture, muscles activity, holding time, and workplace and foot wear conditions as subjects of study [3], [11], [27], [29], [31], [33], [42]. The mentioned risk factors are significant contributors to discomfort and fatigue among workers who performed processes jobs in standing position.

Another risk factor that should be taken into account in the study of standing jobs is whole-body vibration (WBV). In manufacturing industry, for example, metal press operators perform metal stamping operation in standing position. Besides performing the operation in continuous standing, the operators are exposed to mechanical vibration due to high and repetitive impact between the machine's plunger and the die. The cyclic load transfers its vibration to the workers' body through the machine foundation and thus poses WBV. Many studies believed that continuous exposure to WBV initiated muscle fatigue and increased the risk of lower back pain [52], [53], [54], [55]. A study using sEMG revealed that the WBV has contributed muscle fatigue and low back pain during prolonged seating [56]; however, the effects of WBV in association with prolonged standing require further research works.

As discussed in the previous sections, control measures through administrative and engineering controls have been widely applied to minimize discomfort, fatigue, and injuries associated with prolonged standing jobs. In addition to administrative and engineering controls, this paper proposes another method called Knowledge-Based Systems (KBS). The KBS is a class of computer programs that can advise, analyse, categories, communicate, consult, design, diagnose, explain, explore, forecast, form concepts, identify, interpret, justify, learn, manage, monitor, plan, present, retrieve, schedule, test and tutor [57]. With numerous facilities offered by KBS, an advisory system that can manage standing jobs safely should be established to assist ergonomics practitioners or safety and health engineers to redesign or improve the existing standing workstation in their workplaces. The knowledge embedded in the advisory system can provide analysis of risk factors associated with prolonged standing jobs and alternative solution for the workstation design to minimize discomfort and fatigue. In other applications, a KBS has been developed to minimize risk of hands and wrists injuries [58], and quantify WMSD associated with shoulder and neck pains experienced by industrial workers [59], [60].

6. OVERALL CONCLUSIONS

Based on review of the literature, it can be concluded that performing jobs in prolonged standing has contributed numerous health effects such as work-related musculoskeletal disorders, chronic venous insufficiency, preterm birth and spontaneous abortion, and carotid atherosclerosis. However, those injuries can be minimized through application of engineering and administrative controls.

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